Atmospheric Forcing and Its Spatial Variability Over the Japan Sea

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http://www.unc.edu/~ascotti/jes

LONG-TERM GOALS

The long-term goal of this study is to improve our understanding of the marine atmospheric boundary layer (MABL), its spatial structure and variability, and the resultant ocean surface forcing over the Japan/East Sea (JES).

OBJECTIVES

The main objectives are (1) to determine the structure and variability of the MABL over the JES on synoptic and seasonal time scales, (2) to estimate surface wind stress and heat flux time series during summer and winter conditions, and (3) to examine the role of the coastal mountain ranges along the western perimeter of the JES on the low-level air flow and surface forcing during winter, with special emphasis on cold-air outbreak events.

APPROACH

This study is part of the ONR Japan/East Sea Directed Research Initiative to examine frontal processes, circulation, and water property evolution in the Japan/East Sea during 1999–2000. Our approach is to (1) make ship and fixed-point meteorological measurements on selected JES cruises to investigate MABL structure and surface forcing variability during summer (1999) and winter (2000) conditions, (2) collect and analyze JMA buoy weather data, regional WMO surface and upper-air data, stationary weather satellite imagery, and ECMWF surface fields to determine the synoptic setting during our *in-situ* measurement periods, and (3) conduct a process-oriented model study to gain dynamical understanding of the wintertime orographically modified flow, and to compare these model flows to observations and to results from more complex models.

WORK COMPLETED

Meteorological data were collected on three R/V *Revelle* and two R/V *Professor Khromov* cruises during summer 1999 and winter 2000 in the JES (Table 1). These measurements included (a) basic shipboard measurements of surface variables (wind, air temperature, relative humidity, air pressure, incident short- and long-wave radiation, precipitation, and sea surface temperature) on all five cruises, (b) balloon soundings (winds, air temperature, relative humidity, and air pressure) to 10 km on the two *Revelle* SeaSoar cruises, and (c) high-frequency sonic measurements of wind velocity, temperature and relative humidity on the winter *Revelle* cruise.

The basic surface measurements were made on the *Revelle* using the ship's IMET system and on the *Khromov* using WHOI self-contained ASIMET units. During the two *Revelle* SeaSoar cruises, two SDSU sensor sets were deployed on the bow mast below the IMET sensors, and one SDSU set near the top of the main mast, providing profile measurements over the maximum vertical sensor spacing available. The winter *Revelle* cruise featured additional IMET and ASIMET radiation sensors and Edson's 3-axis sonic anemometer/thermometer/motion sensor system (Edson *et al*., 1998) mounted on the bow mast to allow direct covariance estimation of surface forcing during high wind cooling events.

Despite some IMET and ASIMET failures, the overall data return and data quality of the surface measurements were good. These data plus some additional data collected during the cruises should allow a full description of the surface meteorological conditions during the five cruises, plus bulk estimation of the surface wind stress during the five cruises and the surface heat and moisture fluxes on the two *Revelle* SeaSoar cruises and both *Khromov* cruises. Atmospheric soundings made on both *Revelle* SeaSoar cruises, from the surface to above 10 km, captured changes in the vertical structure of the MABL during synoptic shifts and winter cold-air outbreaks.

Additional meteorological data have been obtained from a new automatic weather station installed in Vladivostok in late1999 with help from Y. Volkov (FERHRI), other fixed surface stations including Japanese Meteorological Agency buoy 21002, and the WMO upper air sounding stations surrounding the JES. Weather satellite imagery and SST data are also being collected and archived.

A project website (http://www.whoi.edu/science/PO/japan_sea) gives a basic description of this component. Time series of surface met and surface forcing are available at (fttp://ftp.whoi.edu/pub/users/mcaruso/jes) and preliminary model results at (http://www.unc.edu/~ascotti/jes).

Table 1.
JES cruises featuring meteorological measurements collected by this component.
The surface met data sets are considered "complete" if accurate time series of wind velocity, air temperature, relative humidity, pressure, incident short- and long-wave radiation, and SST can be constructed using the best mix of IMET, ASIMET, SDSU, and other shipboard data.

Ship	Dates	Chief Scientist	Activity	Surface Met Data	Other Data
Revelle	5/19–6/3/99	Lee (UW)	SeaSoar	Complete	Sounding
Revelle	6/25–7/18/99	Talley (SIO)	Hydrography	No Shortwave Radiation	
Khromov	7/20–8/9/99	Talley (SIO)	Hydrography	Complete	
Revelle	1/16–2/4/00	Lee (UW)	SeaSoar	Complete	Sounding, Turbulence
Khromov	2/28–3/17/00	Talley (SIO)	Hydrography	Complete	

We originally hypothesized that the Vladivostok "Gap" in the coastal mountain range would tend to channel the eastward flow of cold surface air during cold-air outbreaks, thus affecting the surface wind field over the western JES. Using the Rogerson (1998) nonlinear shallow water MABL model, initial model simulations with idealized topography show a strong jet leaving the gap and veering westward, indicating topography, stratification, and rotation are tightly coupled as first thought.

RESULTS

Three cold-air outbreaks occurred over the JES during the winter Revelle cruise, and our shipboard meteorological measurements allow an initial characterization of the surface forcing and MABL structure during these events. Each cold-air outbreak features a sharp drop in air temperature below 0°C accompanied with sustained, predominantly southward winds above 10 m/s that last at least 24 hours (Figure 1). The wind stress magnitude can exceed 0.4 N/m^2, and the net surface heat loss can exceed 500 W/m^2. The short-wave contribution to the heat flux is relatively weak due to the time of year and the generally overcast skies, and is more than offset by the net long-wave loss. The dominant heat loss is due to the latent and sensible components, which are both large because of the relatively large air–sea temperature difference, the moderate relative humidity, and the high wind speeds in the outbreak events. The average fluxes for the two-day period January 24–25 during the second cold-air outbreak event are: wind stress: 0.4 N/m^2; air temperature: -8.5°C; SST: 4.8°C; relative humidity: 67%; Q_{net}: -490 W/m^2; Q_{sw}: 33 W/m^2; Q_{lw}: -61 W/m^2; Q_{sen}: -262 W/m^2; Q_{lat}: -199 W/m^2. For the entire cruise, the mean radiation heat gain was 8 W/m^2 and the mean air-sea flux loss was 296 W/m^2, resulting in an average net heat loss of 288 W/m^2.

There is considerable variation in the vertical structure of the MABL over the Japan East Sea. The ocean surface is almost always warmer than the overlying air, causing the low-level air to be unstable, high humidity and well-mixed vertically for a few hundred meters. Usually, the air is from the NW and there is an air temperature inversion between 1 km to 2.5 km elevation, with very dry air above. Winds above 2–3 km tend to be faster than those below, from the west and increasing in speed with elevation.

During the initial stage of a cold air outbreak, surface winds are more from the N or NNE, with MABL temperatures falling to -10°C, and the lower atmosphere well-mixed, nearly saturated and without an air-temperature inversion. In the latter stages of a cold air outbreak, a weak inversion forms around 1.5–2 km and the winds below the inversion winds may be stronger than those above.

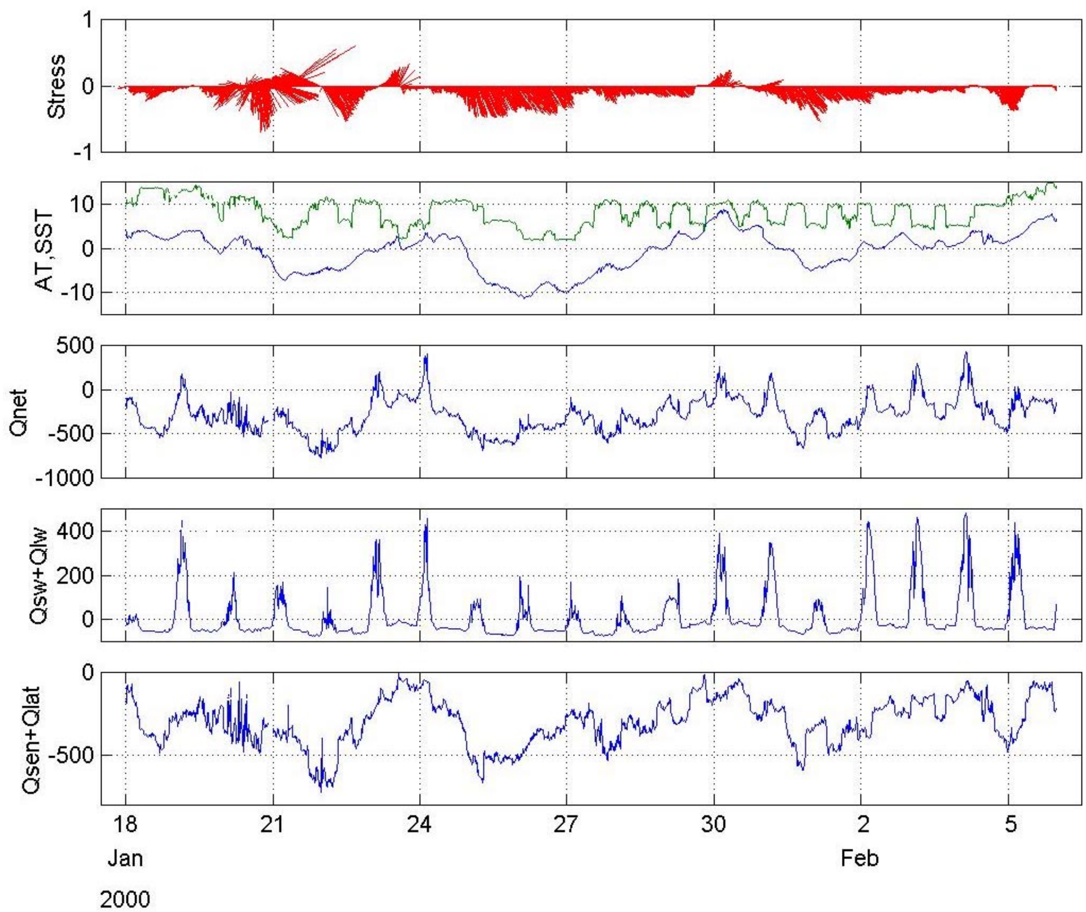

Figure 1. Time series of the vector wind stress (top panel), air (blue) and SST (green) temperature (second panel), net heat flux into ocean (third panel), the net short- and long-wave radiation heat flux (fourth panel), and the net sensible and latent heat flux (bottom panel) during the winter SeaSoar cruise on the R/V Revelle. Units: wind stress, N/m^2; temperature, °C; heat flux, W/m^2. Fluxes computed following Beardsley et al., 1998.

IMPACT / APPLICATIONS

None.

TRANSITIONS

None.

RELATED PROJECTS

This study is part of the ONR Japan/East Sea DRI. The atmospheric measurements, compiled observational and model products, and the idealized model results will be relevant to many of the other projects in the DRI. We plan to combine our ship and fixed-point measurements with winter aircraft observations made by C. Friehe (UC-Irvine), drifter wind and pressure measurements collected by P. Niiler (SIO), and other data to describe specific cold-air outbreak events and associated surface forcing fields. S. Chen (U. Miami) plans to use our *in-situ* atmospheric observations in her 3-D meso-scale model assimilation and validation work. Results from our idealized shallow-water modeling will be compared with her model simulations, with emphasis on understanding the dynamics of the orographically modified flow. Comparisons of our estimates of wind stress and heat flux with those from NOGAPS and ECMWF models will provide important clues about the accuracy of these model fields and their usefulness in JES ocean circulation simulations made by R. Preller (NRL) and other investigators.

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PUBLICATIONS

None.